SUFFICIENT STIFFNESS MAKES GAP MOVEMENT INDEPENDENT OF EXTERNAL FIXATOR MOUNTING

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Introduction It is widely accepted, that mechanical stability of monolateral external fixators has an effect on the healing progress and clinical outcome\(^1\). The mounting plane of external fixators, however, is usually selected according to surgical needs and appropriateness of the surgical approach. Recent analytical analyses suggest a considerable influence of the mounting plane on fracture gap movement in fractured sheep tibia\(^2\). Hypothesis of the current work was that a sufficiently high stiffness of an external fixator minimizes the influence of fixator mounting on gap movement. Goal was to determine interfragmentary movement for different mounting planes of external fixators and correlate these in vivo findings to analytical predictions of gap movements from a computer model.

Materials and Methods Two groups of six healthy female Merino sheep (two years, mean weight 77 kg, range 59 – 90 kg) received a standardized osteotomy of the right tibia (3 mm gap) under general anesthesia. For fracture stabilization, group 1 was supplied with a medially mounted AO mono-lateral fixator while in group 2 the identical fixator was mounted antero-medially. Both fixators were constructed in an identical manner and consisted of three proximal and three distal Schanz’ screws (Ø 5 mm), and two carbon fiber rods (Ø 10 mm). The distance between skin and inner rod was 5 mm. Additional Schanz’ screws for measurements of gap movement were mounted proximally and distally to the fracture gap. These additional screws were not connected to the frame and served solely for measurement purposes. Limb loading was monitored pre- and postoperatively (Emed, Novel, Germany). Gap movements were recorded using reflective markers attached to the measurement screws and an infrared optical measurement system (PCReflex, Qualisys, Sweden). During gait, movements were recorded up to three times per week for a 3 weeks period (Fig. 1). The 3-D stiffness of the external fixator construct was determined in vitro using two cadaver tibiae (Zwick, Germany)\(^3\). Mann-Whitney-U tests were used for statistical analysis (SPSS 8).

Results Animals unloaded the operated limb during the first week but returned to full weight bearing thereafter. In group 1 axial compression was 0.7±0.3 mm (mean ± SD) and shear 2.4±0.5 mm during the initial measurement (Fig. 2). In group 2 axial compression was 0.7±0.2 mm and shear 2.3±0.4 mm (Fig. 3). Movement magnitudes and orientations decreased slightly during monitoring. The computer simulation of the gap movements predicted compression of 0.8 mm and shear of 2.1 mm for group 1 (Fig. 4) and compression of 0.8 mm and shear of 1.9 mm for group 2. In vitro fixation stiffness was 1345 N/mm in compression, 11 Nmm\(^{-1}\) perpendicular and 22 Nmm\(^{-2}\) parallel to the fixator mounting plane.

Discussion No statistically significant difference could be observed in the in vivo measured gap movements between group 1 and 2 in compression and shear (p>0.05). The magnitude and orientation of gap movements remained similar in both groups during the monitoring period (Fig. 2 & 3). Overall, in vivo measured and calculated interfragmentary movements agree well in magnitude and orientation (Fig. 4). Slight differences in magnitude might be related to simplifications in modeling and the initial unloading direct post-operatively. Nevertheless, the findings of the current study suggest that analytical analysis of musculoskeletal loading may be a valid method to predict mechanical conditions at the fracture site. If used in pre-operative planning, this method may help to optimize the mechanical conditions at the fracture site and thereby support the biological process of healing.

The monolateral fixator used in this experiment appeared to be rather stiff compared to previously reported data (AO monolateral, 4 screws: 425 N/mm axial, 8 Nmm\(^{-1}\) perpendicular and 36 Nmm\(^{-2}\) parallel bending stiffness\(^4\)). The results of the current experiment support the hypothesis that a rather stiff external fixator makes gap movements independent of the specific mounting plane. In combination with the results from previous analyses\(^5\), it can be concluded that less stable external fixators tend to be dependent upon the specific mounting plane.

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References

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